# NSLS-II Accelerator Commissioning

## NSLS-II Accelerator Systems Division

## Revision 1

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# 1.Introduction

## 1.1 Commissioning Plan as part of the Project Start-Up and Test Plan

A **NSLS-II Start-up and Test Plan** has been established as a Framework of documents which clearly identifies the requirements for

- Documentation readiness,
- Technical readiness,
- Personnel Training and Qualification,
- Hardware and Software Testing,

and which defines the acceptance criteria for CD-4 at the end of commissioning. Hardware and software testing includes the following elements:

- sub-system testing and qualification,
- integrated system tests,

- **commissioning with beam.**

The present **Commissioning Plan** describes the requirements to perform commissioning, the assumptions on boundary conditions for commissioning, the goals of commissioning, and detailed plan to carry out commission in several phases.

## 1.2 Definition of Commissioning

Definition: In the following the expression "**Commissioning**" refers to the particular mode of accelerator operation with beam which aims to

- test the function of accelerator hardware and software with beam,
- verify in particular the proper functioning of the equipment protection system,
- verify the adequacy of radiation safety shielding, the proper functioning of area radiation monitoring, and the Loss Control & Monitoring System to minimize radiation dose experienced by humans,
- check the integrity and the consistency of the subsystems as built
- develop refined settings of the hardware components to allow efficient injection, and storage of accelerator beams with good stability, beam intensity, the advertised beam parameters, and good beam lifetime,
- condition accelerator hardware systems with beam for optimum performance
- develop and calibrate the accelerator model
- develop and document the procedures which are necessary to operate the accelerator routinely and to
- perform continuous improvement and development.

## 1.3 Purpose of Commissioning Plan

Commissioning is the last step which needs to be successfully performed in order to complete the project and obtain Department of Energy (DOE) approval for operations.

The commission plan laid out in this document needs to be understood as a developing plan which is being optimized and refined as more details will become available and decided upon in the design and construction process of the facility and in particular of accelerator systems.

The requirements for optimum and effective commissioning and the corresponding need of what needs to be The assumptions concerning commissioning affect the scheduling decisions, the design of hard- and software components and the definition of the technical test program. These assumptions are spelled out explicitly to ensure

- that all involved in preparing for commissioning have the same base of information and understanding and commissioning planning can proceed as a coordinated process,

- that a structured process can be applied to clarify the implications and the interdependence of the assumptions which will lead to an optimized set of conditions and final plan for commissioning,

- that logical flaws in the present planning are discovered early and corrected,

- that the resources to prepare commissioning are in place when needed.

The intention is to mature this document by detailed decisions and assessments among the NSLS-II staff in order to produce to produce a detailed, well thought through Commissioning Document which will be the basis for detailed commissioning plans.

## 2.Commissioning Authorization

DOE is the approval authority to allow commissioning. This approval authority has been delegated to the Brookhaven Site Office (BHSO) for the NSLS-II accelerator. This approval requires a detailed authorization process which addresses all of the relevant issues such as completeness of documentation, technical readiness, the training of the staff, the existence of detailed commission procedures, the assessment of hazards, safety and emergency procedures.

### 2.1 Guiding Documents

The NSLS-II Authorization Base (AB) is defined by the requirements and the guidance in:

- DOE Order 420.2B "Safety of Accelerator Facilities"
- DOE Guide 420.2-1 "Accelerator Facility Safety Implementation Guide"
- DOE Order 413.3B "Program and Project Management for the Acquisition of Capital Assets"
- BNL SBMS Subject Area "Accelerator Safety"
- BNL SBMS Subject Area "Conduct of Operations Matrix Development"
- 10 CFR 835 "Occupational Radiation Protection Program"
- 10 CFR 851 "Worker Safety and Health Program"
- BNL Standards Based Management System

### 2.2 Commissioning Modules

The NSLS-II strategy is to break the Authorization Base process into four modules, consistent with 420.2B, that coincide with the accelerator equipment installation & operations. The 4 modules are:

- LINAC (including LINAC to Booster Transfer Line)
- Booster (including Booster to Storage Ring Transfer Line)
- Storage Ring
- Full Operations (roll-up of first three modules)

### 2.3 Elements of the Authorization Base

Each module will have the following components which are concluded by authorizations and reviews:

#### 2.3.1 Safety Assessment Document

The Safety Assessment Document (SAD) is required by DOE order 420.2B. It should identify hazards including associated impact on humans and describes them sufficiently as to obtain understanding of the associated risks. It further will describe the technical and administrative measures to eliminate or minimize the hazards. It should reference or describe the function, location and organization of the facility and describe or reference technical details of major components. The SAD can be broken up in individual documents for major modules of the facility. The SAD needs to be updated if the facility is developed or the framework (DOE safety order) is changing. The SAD produced by the project team. It is reviewed and approved by the Laboratory ES&H Committee and the Laboratory DD officer.

### 2.3.2 Accelerator Safety Envelope

The Accelerator Safety Envelope (ASE) is also required by DOE order 420.2B. The purpose of the ASE is to define the physical and administrative bounding conditions (for example limits in beam energy and beam intensity) for safe operations based on the safety analysis documented in the SAD. The ASE, based on an approved SAD, is submitted by the DDO to BSHO for approval.

### 2.3.3 Authorization Plan and Commissioning plan)

This is this document. It should be noted that that the Contractors for the LINAC and the booster synchrotron have been asked to create a commissioning plan of their own. These topics for these commissioning plans are also addressed in this document.

### 2.3.4 Operational Controls

This set of documents contains training records of personal, component specific training programs, operational procedures, the operational structures and the responsible persons, and an operations plan which details how operation is going to be performed

### 2.3.4 NSLS-II Readiness Evaluation

This is a NSLS-II internal process to review readiness. The documented review process including the follow ups and action items responses is part of the authorization base.

#### 2.3.4.1 Accelerator Readiness Review

The accelerator readiness review (ARR) is the final, high level review which verifies that all steps in the authorization base are complete and well documented.

The process to enable BHSO to authorize commissioning is summarized in the block diagram below (figure 1.)

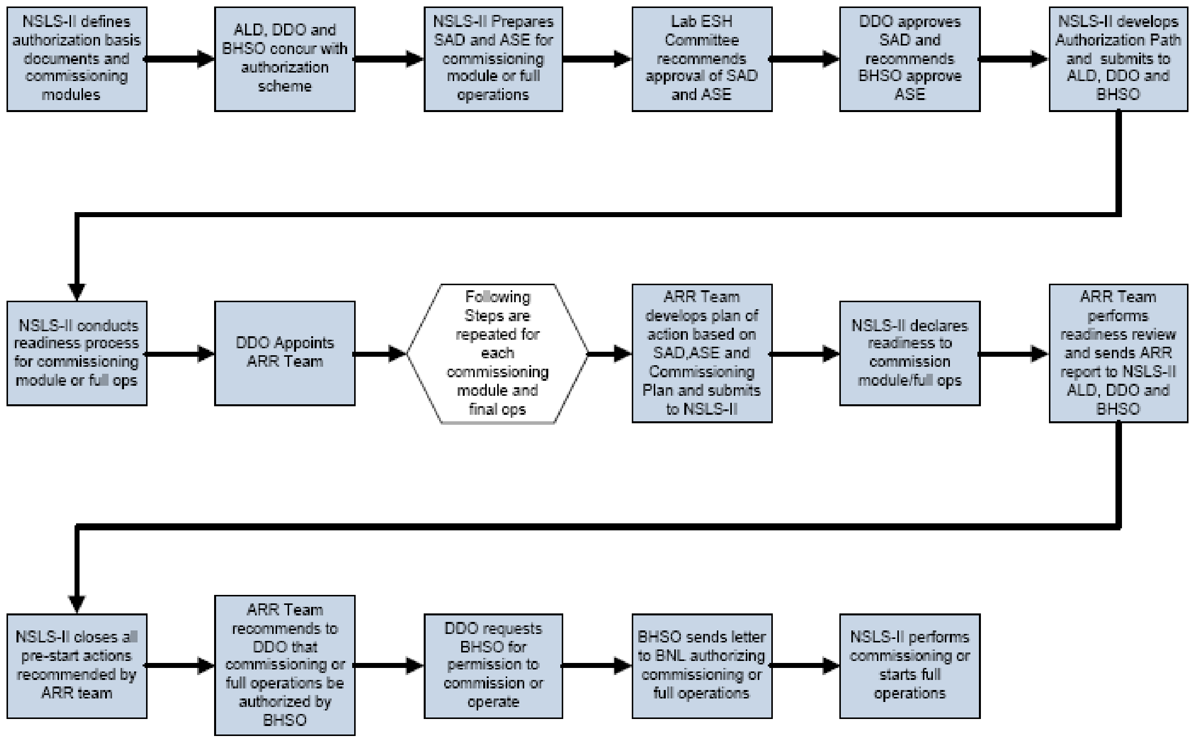



Fig 1: Block diagram summarizing the process to obtain permission to start commissioning

## 2.4 Goal of the Authorization Procedure

After these processes have been completed it can be assumed that:

- All accelerator hardware systems have been properly tested,
- All procedures to turn on, turn off, repair and perform maintenance of accelerator components have been defined and technical back-up information is in place,
- All roles in the commissioning process have been defined,
- All staff participating in commissioning has been properly trained according to the requirement of the individual's particular involvement.
- An acceptable SAD (or its equivalent) has been properly developed in accordance with DOE O 420.2B requirements, and has been reviewed and approved in accordance with the contractor internal safety review system.
- An adequate ASE has been developed in accordance with the accelerator safety order (ASO) and is supported by the SAD.
- An appropriate commissioning plan has been developed.

- An appropriate unreviewed safety issue (USI) process has been developed. (At this points there are no plans to use the USIprocess).

- Procedures necessary for the safe operation of the activity have been developed, reviewed, and approved, and an appropriate process for the development, review and approval of new and revised procedures is in place.

- Procedures to deal with abnormal and emergency situations have been prepared and are approved for use.

- Records important for operational and post-operational activities are controlled.

- Equipment and systems having safety importance meet criteria established in the SAD and have been appropriately tested.

- Training and qualification programs relevant to safe operation in compliance with the ASO and ISM have been established.

- Staffing requirements specified in the ASE are met.

## 3. Commissioning Staging

The accelerator commissioning will extend over a 2 year period. There are five well defined stages (not to be confused with the "modules" in the Authorization Base process) which are clearly distinguished in the schedule. These stages correspond to the modules for obtaining authorization but they are not identical. The requirements will not be the same for each of these stages. The LINAC commissioning does not dependent on as many conditions as the storage ring commissioning and most of the requirements and assumptions refer to the storage ring. Particular requirements for the various stages will be marked explicitly if they are not specific for the storage ring. The successful completion of these five commissioning stages will be a necessary condition for the early finish of the NSLS-II project.

The stages are:

### 3.1 LINAC Front-end

The LINAC front-end consists of the LINAC gun and the first stage of sub-harmonic bunching including low power RF sources and first focusing elements. This part will be delivered earlier than the linac which allows separate commissioning of this component. Linac front-end commissioning and tests will be performed in the RF Laboratory in Bld. 832. The beam energy is low (100keV). Because of the nature of this device, the linac front-end will be considered as a Radiation Generating Device (RGD) and will not be subject to the authorization process involving BSHO as required for all other commissioning stages. The purpose of the separate commissioning of the LINAC front-end is to study operation modes for special requirements (single bunches of high intensity, arbitrary bunch patterns). It is assumed that if the early study on front-end is successful; the LINAC commissioning will concentrate on the standard operation mode (multi-bunch) once the entire LINAC is available.

## 3.2 LINAC

The LINAC commissioning will include the parts of the LINAC-to-Booster Transfer Line which are in the LINAC building. This includes the primary dump and the diagnostic beam dump. The LINAC commissioning will be performed by the LINAC vendor who is responsible for complying with the Commissioning Plan and for reaching the performance specifications, as well as confirming area monitor response and adequacy of shielding. NSLS-II must provide the Master Oscillator signal (499.68 MHz +/- 10 kHz at 0 dBm). NSLS-II shall also provide an event generator with the programmed events (or triggers) for modulator, gun enable. The vendor shall provide the event receiver. NSLS-II staff will support the commissioning activities to the extent accepted by the vendor. The transfer line part of LINAC commissioning will be performed by NSLS-II staff. An important assumption is that shielding is sufficient to guarantee that work in the booster tunnel must be allowed to continue during LINAC commissioning. This assumptions needs to be tested and verified as part of the commissioning program.

## 3.3 Booster

Pre-commissioning tests will include inspection of the radiation shielding and tests of the personnel protection system. The required safety documentation will be prepared, reviewed and signed before the booster commissioning. All personnel, both NSLS-II and vendor's, will have required safety training.

**Table 1. Parameters for the NSLS- II Linac during Commissioning phase**

| | |
|---|---|
| Nominal energy | 200 MeV |
| Minimum Energy with single klystron failure | 170 MeV |
| Repetition rate $f_{rep}$ | from single shot to 10 Hz |
| Geometric Emittance, $4\sigma x \sigma x'$ | 200 nm-rad at 200 MeV |
| Energy spread ΔE/E | <1.0% rms |
| Pulse to pulse energy jitter | < 0.5% rms |
| Pulse to pulse time jitter | <150 ps rms |
| **Short pulse mode** | |
| Length of a single bunch at 500 MHz repetition rate | < 330 ps |
| Time structure | 1 single bunch to bunch trains with separation between consecutive bunches of 2 to 10 ns. |
| Maximum charge per bunch $Q_b$ | 0.2 nC |
| Relative bunch purity before and after pulse | < 5% |
| **Long pulse mode** | |
| Pulse train length | 160 – 300 ns |
| Corresponding number of bunches at 500MHz repetition rate | 80 – 150 |
| Maximum charge per pulse train | 5 nC |
| Relative charge difference between bunches in the pulse | < 20% |

The Booster commissioning will be performed by the Booster vendor who is responsible for developing and complying with the Commissioning Plan as well as reaching the performance specifications, confirming area monitor response and adequacy of shielding. NSLS-II staff will support the commissioning activities to the extent accepted by the vendor. The booster commissioning requires satisfactory performance of the LINAC-to-Booster Transfer Line, in particular the part in the booster tunnel. Prior to the booster commissioning the NSLS-II project will demonstrate to the booster vendor satisfactory performance of the linear accelerator, booster RF system and linac to booster transport line. To this end the project shall demonstrate to the Booster Vendor, that the LINAC beam parameters as measured in the LTB transfer line diagnostics are consistent with the parameters in Table 1.

To avoid any time gap between booster installation and testing and booster commissioning, the transfer-line has to be commissioned during the night in the integrated testing phase. Linac performance demonstration will include measurement of the main beam parameters using diagnostics and instrumentation of the linac-to-booster transport line. The NSLS-II staff will provide calibration data for the diagnostics devices to the booster vendor so the booster vendor may check adequacy of the measured beam parameters. Both modes of operations, single- and multi-bunch will be demonstrated prior to the booster commissioning.

The linac-to-booster transport line will be fully functional including all the beamline subsystems. Beam line vacuum will be measured at the designed level. Beam studies will be carried out to test magnets, power supplies and beam diagnostics systems. All calibration constants will be available in the injector database. Prior to the booster commissioning the electron beam with the specified properties will be delivered to the entrance of the booster injection septum.

Since the booster RF system is provided by NSLS-II, the project shall demonstrate the performance of the booster RF system including:

- As low as 100 kV cavity voltage for injection energy (200 MeV)
- As high as 1.2 MV for extraction energy (3GeV)
- Ramping between 100kV and 1.2MV with programmable (linear) ramp, triggerable from booster control system
- Continuous phase adjustment of the booster cavity phase relative to the Master Oscillator (which is common to linac
- Amplitude and phase jitter of the booster cavity rf fields to less than +/- 1 % amplitude and +/- 1 degree phase
- Cavity vacuum to less than 1 * 10 ^-7 torr.

Prior to commissioning the booster with RF: (1) the vendor shall demonstrate the injection of the linac beam with the booster RF voltage off and show spiraling beam. Since the synchrotron radiation losses are negligible at the 200 MeV injection energy (10's of eV), several hundred turns shall be achieved to demonstrate booster performance in absence of RF; (2) the NSLS-II staff will demonstrate performance of the booster RF system. This will include full power operation of the booster RF system, ramping the RF cavity voltage using predefined ramp table, tests of amplitude and phase jitter, tests of communication of the RF system with the injector control system, setting and reading back main parameters of the RF system, measurements of the RF cavity vacuum, tests of the RF cavity synchronization and timing system.

The NSLS-II staff will demonstrate performance of the booster-to-beam-dump transport line. Booster-to-beam-dump transport line is the main test bench for the booster acceptance testing. The NSLS-II staff will demonstrate performance of the beam line elements. During the booster design phase the

NSLS-II staff will develop applications for the beam parameters measurement in the transport line. These applications will be tested without the beam before the booster commissioning.

Booster commissioning will be preformed from the injector control room, located in the injector service building. The injector commissioning will be planned in three 8-hours shifts with the accelerator beam activities taking place mostly after normal working hours, in order to: (1) make the best use of availability of the NSLS-II technical staff during normal working hours for optimization of the injector subsystems; and (2) minimize radiation exposure for the personnel working in the areas surrounding the injector complex.

The goal of the booster commissioning is to demonstrate that the quality of the extracted beam is well within the performance specifications. The booster commissioning will include the following steps:

a) Beam injection

During this series of tests the beam from the linac-to-booster transport line will be injected into the booster and guided through the booster injection system. Injection septum and kickers will be ON and beam position and sizes will be observed using the beam flags around the booster. All power supplies will be at the DC level corresponding to the injection energy. Performance of the injection devices will be optimized during this series of tests.

b) Several turns

Booster RF system will be OFF, power supplies will be at the DC level corresponding to the injection energy. Orbit and optics will be corrected so the beam will make several turns around the booster at the injection energy. BPMs and FCT will be tested with the circulating beam.

c) RF cavity ON

Booster RF system will be turned ON, tuned and phased to the electron beam before ramping the RF voltage. Power supplies will be at the DC level corresponding to the booster injection energy. The booster beam will be stored in this mode of operation. During this early stage of Booster commissioning with beam and RF, the tune measurement system will be tested and Booster tunes will be measured and corrected.

d) Energy ramp

Booster power supply setpoints will be ramped according to the ramp tables. All dipole, quadrupole, sextupole and corrector power supplies will have separate ramp tables. These tables will be matched to each other near the injection energy.

e) Energy ramp with the RF system

The booster RF ramp table will be included at this step. All of the ramp tables will be matched to each other for the whole energy range from injection to extraction. Orbit and tunes will be corrected and optimized using the ramp tables. Beam will be accelerated to the nominal extraction energy. DCCT will be tested. Booster will operate during this period subject to outgassing caused by the synchrotron radiation at the high energy. The main booster optics parameters will be measured and corrected using LOCO-type algorithms based on orbit response matrix measurements.

f) Beam extraction

Booster extraction system will be turned ON and synchronized to the circulating beam at the nominal extraction energy. First the slow bump system will be tested and optimized. Next extraction kicker and septa will be turned ON and synchronized to the beam. The extracted beam will be measured using beam flags and BPMs in the booster-to-beam-dump transport line and guided to the beam dump.

g) Booster beam acceptance testing

The extracted beam properties will be measured using diagnostics and instrumentation in the booster-to-beam-dump transport line. The booster system performance will be optimized to reach the specified values.

h) Beam stacking

Beam stacking using two bunch trains separated by the linac cycle period will be injected and accumulated in the booster. After energy ramp the beam will be extracted and the beam parameters will be measured.

These steps will be repeated for three values of the beam charge:

1) First test will be carried out with a single bunch with 0.5nC of charge
2) Test will be repeated with a train of 100 bunches with the total charge of 2nC
3) Test will be repeated with trains of 80 to150 bunches with the total charge of 15 nC.

The adequacy of shielding will be confirmed during each of these tests. Response of the radiation area monitors and the LCM system will be evaluated for each test cycle also.

During commissioning the booster performance will be reliability tested for the period of 8 hours of uninterrupted beam delivery. The beam parameters will be monitored during this time.

Radiation monitoring will be tested during the booster commissioning. All engineering controls and administrative measures specified in the Accelerator Safety Envelope will be in place.

All daily results will be logged into an electronic log. During day time the vendor and NSLS-II staff will process the beam measurement and prepare input for the evening studies. The vendor will educate the NSLS-II staff on the applications and procedures developed for the booster system. After the commissioning the vendor's applications will be integrated into the global NSLS-II control system.

At the end of the commissioning the booster operations will be carried out from the main control room.

Booster commissioning must allow work to continue in the storage ring tunnel.

## 3.4 Storage Ring Commissioning Phase 1

### 3.4.1 Commissioning Goals

The main beam parameters of the storage ring associated with the goals of the commissioning phase 1 are referenced in table 3.4.1.

Table 3.4.1 Goals of Main Parameters of Storage Ring Beam for Commissioning (to be updated)

| **Parameter** | **Unit** | **Goal Phase 1** | **Goal Phase 2** | **Base line** |
|---|---|---|---|---|
| Beam Energy | GeV | 3 | 3 | 3 |
| Peak Beam Intensity | mA | 100 | 300 | 300 |
| Horizontal Beam Emittance | nm·rad | 2.5 | 1 | 1 |
| Vertical Emittance | pm·rad | 25 | 10 | 8 |
| Hor Beam Stability | % $\sigma_x$ | 10 | 10 | 10 |
| Hor Beam Stability | % $\sigma_y$ | 10 | 10 | 10 |
| Bunch Length | mm | 3 | 3 | 2 |
| Energy Spread | % | 0.2 | 0.4 | 0.9 |

| | | | | |
|---|---|---|---|---|
| Horizontal Damping Time | ms | 125 | 65 | 65 |
| Vertical Damping Time | ms | 125 | 65 | 65 |
| Longitudinal Damping Time | ms | 62 | 33 | 33 |
| Injection Efficiency | % | 90 | 95 | 95 |
| Residual Orbit | μm | 5 | 5 | 5 |
| Corrected Chromaticity (h/v) | 1 | 2 | 2 | 2 |
| RF Voltage | MV | 2 | 2 | 2.5 |

Storage ring commissioning phase one will include the booster-to-storage-ring transfer line and, in particular, the part which is in the storage ring tunnel. The storage ring will first be commissioned without insertion devices.

This part of commissioning is aimed to demonstrate:

- that storage ring beam optics model is adequate
- provide calibration and empirical correction of the model
- beam based alignment
- the main performance parameters,
- adequacy of correction systems
- adequacy of radiation safety shielding, the proper functioning of area radiation monitoring, and the LCM system to minimize radiation dose experienced by humans,
- adequacy of beam instrumentation
- orbital stability
- RF stability
- cryogenic stability
- beam stability
- vacuum integrity
- functioning of equipment protection system
- high intensity operations

### 3.4.2 Assumed Achievement of Pre-Commissioning

Pre-commissioning tests will include inspection of the radiation shielding and tests of the personnel protection system. The required safety documentation will be prepared, reviewed and signed before the storage ring commissioning with electron beam begins. All personnel will have required safety training. Before injecting beam into the storage ring, testing will be completed verifying that named devices in the computer control system indeed are connected to the correct hardware. Polarities of all magnets will be checked. The survey of the magnetic elements will be completed with achievement of the required strict tolerances. Testing of beam diagnostics which can be carried out without beam will be completed.

### 3.4.3 Initial Beam Studies

Initial beam studies in the storage ring will be aimed at achieving first a beam surviving a single revolution. This can be achieved by centering the beam in one downstream kicker and adjusting the kicker timing and strength to place the beam on the design orbit. The single turn capability of the BPMs will enable the steering of the beam trajectory around the ring and can provide information on the linear beam optics.

A flag will be available to provide position and beam size information at the injection point and after one turn. The diagnostics applied to the first turn can provide important information about possible magnet errors that may have escaped notice in the hardware tests.

Further beam studies will be aimed at achieving additional turns around the ring with the goal of establishing circulating beam surviving hundreds of turns. Measurement of the orbit of such a circulating beam can allow the improvement of the orbit by use of the corrector magnets. Reasonably accurate measurement of the tune can be made. After the achievement of circulating beam, the RF will be turned on and properly phased to the electron beam. Once RF capture is achieved the beam should survive for many seconds or minutes. This will allow better measurements of orbit and tune.

After RF capture has been accomplished, the four storage ring injection kickers can be used to make a local bump. This will allow the 1-Hz accumulation of many injected bunches into the storage ring, and hence the achievement of a few mA of stored current in the ring. With stored beam current of a few mA, more accurate tune measurement will be possible and the BPMs will provide more accurate measurements of orbit. This will allow more precise orbit correction. Measuring the matrix of orbit response at each BPM due to each correction magnet, we will use the LOCO algorithm to determine the linear optics. If necessary, individual quadrupole gradients will be adjusted to improve the linear optics. Use of the x-ray pinhole cameras will make it possible to image the transverse profile of the beam. This will provide important information on the linear optics as well as on the effect of the kickers on the stored beam during injection.

Further injection studies will concentrate on improving injection efficiency and RF capture. Efforts will be made to minimize the loss of stored beam when the injection kickers are fired. In this manner the stored current will be increased. As the current is increased the vacuum pressure will rise and it will be necessary to run continuous injection to clean the vacuum chamber walls using the emitted synchrotron radiation. As the vacuum conditioning proceeds, it will be possible to store increased current with the aim of reaching the first goal of 25 mA.

Measurements of beam lifetime will be made and correlated with vacuum pressure and total Amp-hrs of beam. Skew quadrupoles can be used to adjust the horizontal-vertical coupling. Correlation of the lifetime with the vertical beam size as measured using the x-ray pinhole cameras will give information on the Touschek lifetime. Measurements of correlation of lifetime with the position of beam scrapers will give information on the beam physical and dynamic aperture. Use of a diagnostic kicker (pinger) will enable more direct measurements of dynamic aperture.

As the quality and intensity of the electron beam improves, the precision of the results of the beam diagnostics will also improve. This will allow improved orbit correction to the level of a few hundred micron accuracy. At this point, beam based alignment of the BPMs by centering the beam in the quadrupoles will be applied. This should allow us to center the electron beam in the quadrupole and sextupole magnets to a precision of 30 microns.

### 3.4.4 High Intensity Commissioning

It is important to increase the beam intensity at an early stage in order to identify any problem with high beam intensity. Such problems are usually quite cumbersome. They usually require hardware changes in order to be fixed which is associated with long lead times and small windows of opportunities for implementation. In case of the absence of unpleasant surprises, the beam intensity is not expected to be limited below 100mA. However storage of 100 mA requires good control of the beam and its parameters and a minimum of machine protection.  Functional tests of machine protection systems with beam are an important part of early high intensity commissioning.

High intensity commissioning will require a controlled process to increase intensity and verification that shielding and ALARA measures provide adequate protection against radiation hazards.

## 3.5 Storage Ring Commissioning Phase 2

This part will include commissioning with insertion devices and frontends.  Before insertion devices can be operated with electron beam, the equipment protection interlock system must be commissioned

### 3.5.1 Test of the Equipment Protection System

The equipment protection system (EPS) will protect the components of the vacuum system from synchrotron radiation created in the magnet fields of the accelerator, in particular the fields of the insertion devices. This system will dump the electron beam if an anomaly is detected:
in instances when the beam closed orbit through the insertion devices deviates from the design orbit by more than the allowed tolerance, in case of vacuum pressure exceeding tolerable values, critical temperature reading are out of limit. The EPS system is flexible and additional input signals can be integrated if needed.

To insure that the equipment protection interlock system protects the vacuum chamber, we shall follow a procedure covering the calibration and testing of equipment protection interlock equipment associated with each individual insertion device. These tasks include:

- Center the photon beam in the exit port **(need to say what monitor!!)**
- Verify gap open/close status properly reported to interlock system
- Measure the BEAM position to provide offset values to be used in  BPM based interlock
- Measure the interlock BPM scale factors by applying known orbit movement
- Adjust the hardware trip points
- Verify the beam is dumped at the specified position offsets
- Set the values in the interlock test file
- Set the values in the micro
- Verify the proper operation of the interlock test

### 3.5.2 Insertion Device Commissioning

Key tasks for insertion device commissioning include:
Survey of the front end fiducial marks on the ID beamline
Establish and save reference orbit (low current)
Commissioning of undulator gap control system for Control room
Baking of the beam line equipment (***with beam?)***
ID front end radiation survey at low current (gap opened)

ID front end radiation survey upon opening front end mask and valve
ID front end radiation survey with varying currents until full current stored beam (gap opened)
ID front end radiation survey at intervals during vacuum conditioning of the safety shutter
Center the ID vertically with respect to the beam
Beam conditioning, out gassing of graphite mask and new shutter
ID front end radiation survey with gap closed low current (~5 mA)
Radiation survey with closed gap at intervals until full current
Measure lifetime vs. gap
Observe orbit and tune shift with varying gap
Measure heating of ID vacuum systems versus beam current (total and bunch current)
Study full current beam stability with gaps closed
Prepare look-up tables for feed forward orbit correction coils
Estimate effects on chromaticity and emittance coupling
Commission undulator gap control system for users
Obtain undulator spectra and measure tuning range
Measure flux and brightness (***need beamlines?)***

**4. Prerequisites of Conditioning**

## 4.1 Prerequisites for Conventional Facilities to support commissioning

Conventional facilities provide the environment for the accelerator as well as the main supply utilities. All must be operational to undertake commissioning. In particular:

- The accelerator tunnel air conditioning systems will be fully functional and operating at specification. (Nominal temperature of 78 ± 1ºF around the entire tunnel, with excursions at any point within limited to ± 0.18 ºF over a 1 hour period. Relative humidity will be controlled to range between a low of 30% (winter) and a maximum of 50% (summer).

- Major settlement of the accelerator enclosures has occurred. This is enabled by –
  - Early construction of the concrete enclosures, as much as 4 years ahead of commissioning
  - The installation of girders and magnets for the storage ring will have been completed approximately one year before the start of commissioning.
  - Final survey and alignment of the storage ring will take place shortly before start of commissioning to allow a maximum time for ground settling.

- All cable conduits and openings in the accelerator enclosures will be properly closed with the required shielding material.

- All heavy construction activities such as excavation, compaction, road construction, and back filling will be completed so that storage ring commissioning will not be disturbed by unusual levels of cultural noise.

- All utilities which are part of conventional facilities, in particular electrical installation, de-ionized water, and chilled water will be installed and operating at specification.

## 4.2 Prerequisites for Accelerator Systems to support commissioning

All accelerator hardware and software systems must be tested in an integrated way (meaning the tests include the control of these systems by the control system).

The following systems must be available and proven by test to be ready to support commissioning:

- The personnel safety system has been thoroughly tested including the interfaces to the accelerator components which prevent beam from being injected and circulated.

- The equipment protection system is fully implemented and tested.

- The control system is fully implemented and all hardware systems can be remotely controlled and monitored. The relational database is fully functional. Information about any component can be retrieved from the control room without extra preparation.

- All application programs (engineering and accelerator physics) deemed necessary for commissioning are available and functionally tested.

- All water cooling systems have been installed and have been tested with loads from magnets and RF components.

- All rack level utilities (water, power, UPS power) have been installed and are operational at specification.

- All injection systems have been installed and tested. Timing has been adjusted and confirmed by measuring the waveform of the pulse.  The proper control of injection elements via the control system has been confirmed.

- The timing system has been implemented and tested. The synchronization of RF systems between injector and accelerator has been tested, including the control of the phase of the injector relative to the storage ring. Control of the timing and synchronization systems via the control system has been tested.

- All magnets and girder systems have been installed well before commissioning and the final high precision alignment according to specifications has been performed shortly before commissioning starts.

- No Insertion devices are installed at the time when storage ring commissioning starts.  This represents the first phase of commissioning without IDs.

- The power supply systems are complete. All technical interlocks have been properly tested. The power supplies are installed in sealed air-cooled racks and temperature control has been verified under full load conditions. Power supply functionality has been verified under control system command. The correct polarities and magnitude of currents of the magnets when powered by the power supplies using the control system have been verified.

- The storage ring vacuum system has attained a quiescent vacuum of at least $2x10^{-9}$ mbar. The functionally of the vacuum interlock and the function of pumps and gate valves has been confirmed. Vacuum instrumentation is installed and tested. Vacuum data can be monitored from the control room and active elements (pumps, gate valves) can be controlled from the control room.

- The liquid nitrogen storage and supply lines for the superconducting RF cryogenic system are installed and operating at specification.

- The cryogenic system for operation of the superconducting cavities is in place and operational, including back-up power for recovery of Helium gas in the event of a protracted power failure.

- Two superconducting cavities are part of the NSLS-II baseline scope and are in principle available for commissioning. Present baseline plans include a single 500 MHz superconducting RF cavity to be installed in the storage ring for commissioning up to approximately 100 mA of beam current. To inject and store above 100 mA the second 500 MHz cavity must be installed due to the limitations of the power amplifier and the fixed coupling of the SRF cavities. The passive 1500 MHz SRF cavity for bunch lengthening will not be installed during the initial beam commissioning. It may be installed at the same time as the second 500 MHz cavity when we pass the 100 mA threshold. The Storage Ring RF cryogenic system, the 310 kW RF transmitter system and the SRF cryo-module are vendor supplied turn-key systems and it is the responsibility of their respective vendors to install and commission the systems without beam. Prior to commissioning with beam the SR RF 310 kW transmitter will be tested at full power into the test load provided by the vendor. The cryogenic system has been tested as a standalone system to its design specifications using the heater installed in the Lq.He Dewar. The superconducting RF cavity is installed, connected to the cryogenic system via the valve box and to the transmitter via the WR1800 waveguide and tested in the tunnel. The RF cavity will first be commissioned with the cyrosystem without RF power using the heater installed in the cryomodule. The cavity will then be commissioned and conditioned with RF power to 2.4 MV. All RF interlocks which are not depending on the presence of beams have been tested. After acceptance testing of the vendor supplied systems testing will continue using the NSLS-II supplied cavity controller and the cavity RF field amplitude and phase specifications demonstrated.

- A full suite of beam diagnostics is installed and tested. Application software is available to monitor these systems in the control room. All equipment is installed in sealed, air cooled racks, including high temperature stability racks where necessary.

- Fast orbit feedback has been implemented and the functionality of the hardware components has been tested without beam.

- The transverse feedback damper system has been installed and tested on the component level.

- LCM system is available and functionally operational. This includes in particular the collimators which needed as part of this system.

# <u>5. Radiation Safety during Commissioning</u>

## 5.1 Status of the personal protection system (PPS)

Before commissioning begins, the personnel protection system, including the area radiation monitors, have been installed completely and fully tested to the extent possible without beam.

There are no final decisions on personal protection systems for the experimental beam-lines. Experimental beam-line commissioning is not part of the baseline scope and is presently planned to take place after the early finish of the project. As the beam lines may not be ready when commissioning starts, it is assumed that the personal protection system for the beam lines will not be fully functioning and will not have been tested for initial accelerator commissioning.

## 5.2 Access to Accelerator Tunnel

- Before beam can be injected all the areas protected by the PPS must have been searched and secured by the electronic survey system of the PPS
- Temporary access to the accelerator tunnel during times when beam operation had been originally scheduled is a standard procedure which is absolutely necessary during commissioning. Temporary access is a controlled process which includes:
- Switching the accelerator into a safe mode where no beam is stored and no beam can be injected
- The temporary access is a completely documented process with times of the access, status of the system, names of the persons to whom access is granted, names of the responsible person for safe accelerator operations (operations crew chief) who grants access.
- The temporary access requires breaking the personal protection system interlock for the section to be entered. Subsequent tunnel search and rebuilding of the interlock areas is required at the end of each access. This needs to be documented including the names of the members of the search crew. At this point, no key access is planned.
- The magnet power supplies will not be turned off (necessarily) and the magnet circuits will not be necessarily grounded as all electrical connections will be covered by safety covers.
- Temporary access requires at least 2 persons.
- It is assumed that under no circumstances the accelerator tunnels will be entered when beam is operated.

## 5.3 Ramp up of Beam Intensity

Radiation hazard is closely related to the beam intensity. Initial beam intensity in the storage ring will be very small compared to nominal (0.1%). According to the assessment of the radiation shielding, no radiation hazards is expected with a safety factor of $>10^3$ at beam intensities that low. Area monitors readings will be monitors to confirm this assessment. Area monitors reading for low intensity will be extrapolated to the next step in beam intensity. This extrapolation is reviewed and discussed with NSLS-II ESH and Radiation Control personnel and each level of intensity before the next step in intensity is made.

The initial beam losses will be large. For initial high intensity studies, it is assumed that the beam losses will be much larger than under optimized normal conditions, especially as fault studies are conducted. It is assumed that in order to arrive at an optimized stage, detailed work plans and controls will be taken to ensure that all radiation exposure is ALARA and within administrative control levels established for commissioning allowed dose levels. Such measures could include the temporary establishment of designated radiological areas, and restricting such studies to certain times in the day or the week. It also includes additional radiation monitoring using mobile monitors.

The LCM will be tested with beam to demonstrate that the location of beam losses can be clearly identified. The assumption that the beam is lost dominantly in the extra shielded area will be confirmed after all system parameters have been optimized. Clear and unambiguous procedures will be written, and operating staff will be trained to follow these procedures before operations with continuous injection of high charge (top-off, high intensity operation) can proceed.

## 6. Storage Ring Commissioning Modules

## 6.1 COMMISSIONING PART I

The following tasks need to be accomplished during Storage Ring Commissioning Part I in order:

### 6.1.1 Establish Initial Beam Operation

Obtain stored beam (first turn steering, multi-turn tuning, RF capture…)
Adjust and verify RF parameters
set up injection for accumulation
first Orbit Correction
first iteration of correcting chromaticity and coupling
first iteration of obtaining acceptable injection efficiency

### 6.1.2 Check out Safety Functions

Confirm Shielding in place
Interlock/Access control system operational
Fencing or other personnel barriers in place
Radiation monitoring equipment calibrated and in place
Safety equipment required for operation of facility
Confirm shielding adequacy through series of fault studies
Confirm adequacy of radiation area monitors
Checkout top-off safety functions
Check-out machine protection system
Check out LCM functionality

### 6.1.3 Fine tuning of Beam Optics

Beam Optics Checks and correction (Response matrix, phase advance, coupling measurements)
Beam based alignment
measurement of chromatic distortions and correction
nonlinear dynamics related measurements and corrections (D.A., amplitude dependent tune shift, width of resonances, higher order chromaticity)
measure 1$^{st}$ and 2$^{nd}$ order momentum compaction factor
measure damping distribution

## 6.1.4. Instrumentation Functionality Tests

### *6.1.4.1 Beam position monitor*

Indentify and fix bad bpm – analyze sum, diagonal & position
Synchronize timing – single bunch fill required
First turn and multi turn data capture/analyze capabilities
10 Hz and 10kHz data test
Establish coarse position and sum calibration
Tunes measurement with TbT data (FFT)
Beam mis-steering interlock tests

### *6.1.4.2 DCCT check out*

Establish beam current calibration
Verify lifetime measurement

### *6.4.1.3 Fill pattern monitor*

Test the filling pattern monitor system
Measure the bunch to bunch current; calibrate with DCCT

### *6.1.4.4 Tune and beam stability monitor*

Test functionality

### *6.1.4.5 Scrapers*

Operations and cross-check vs BPM

### *6.1.4.6 Beam loss monitors*

check with scrapers and/or beam steering
check with lifetime

### *6.4.1.7 BM pinhole camera*

Set up testing
Source size measurements – investigate resolution, exposure time

### *6.4.1.8 3PW pinhole camera*

Set up testing
Source size and energy spread measurement

### *6.1.54.9 Beam profile monitor (using visible light)*

CCD camera to monitor stored beam, measure the horizontal beam size
Gated camera to measure the single bunch, single turn profile
Observe injecting beam profile – to support injector tuning

### *6.1.4.10 Streak camera bunch length monitor*

Bunch length measurement using streak camera
Bunch length vs. single bunch current
Synchronous phase vs. single bunch current
Synchrotron residual oscillation due to RF noise
Injection transient measurement, help to optimize the injecting beam phase and energy
Other measurement during machine study, especially RF cavity related.

#### *6.1.4.11 Transverse feedback*

Feedback delay precise adjustment (single bunch needed)
Characterize the feedback loop
No transverse instability expected, but transverse feedback digitizer could be used as tune monitor system

#### *6.1.4.12 Xbpms Commissioning*

Test Xbpm related software and displays
Test BM Xbpm blades and position readout
Calibrate position readout using beam steering and stage controller

### 6.1.5 Fast Orbit Feedback Functionality Tests

Cell controller 10 kHz BPM data validation
Measure and analyze corrector to BPM response
Measure and analyze overall open loop response
Test global orbit feedback model
Test all global feedback related application programs
Verify diagnostics software functionality
Perform FFTs for BPMs and correctors
Display data for all cell in 3-D display

### 6.1.5 Fine Tuning of Orbit and Emittance

Orbit correction to micron level
dispersion free steering and orbit correction
vertical emittance tuning

### 6.1.6 Synchrotron Radiation Measurements

Measurement of power deposition s and power load
check of temperature monitor system
check of vacuum interlock
check of assumptions on absorber and mask temperatures, monitoring and cooling

### 6.1.7 High Intensity Studies

Set up of high efficient injection
Set-up of RF feedback and fine tuning of feedback parameters and LLRF

Single Bunch Intensity Limit measurements
bunch lengthening by 3rd harmonic cavity
beam lifetime vs bunch length and bunch intensity study
BCS and ALARA studies with high intensity
Vacuum conditioning beam
RF conditioning with beam
transverse damper test
Study of high multibunch intensity limitations

## 6.2 COMMSIONING PART II

The following tasks need to be accomplished during Storage Ring Commissioning Part II in order:

### 6.2.1 Safety Related Measurements

Check front-end PPS safety assumptions and functions
Check-out and calibrate frontend EPS
Check top-off safety function

### 6.2.2Beam instrumentation check out

Test small gap RF beam position monitors
Test interlock system with local steering
Test ID xbpms electronics

### 6.2.3 ID Integration ( x 8)

Turn on insertion devices one-by-one
correct orbit
measure and correct beam optics
Correct chromatics
adjust and test gap-closing feed forward
measure dynamic aperture
test micron size beam stability in FE

### 6.2.4 Preparation of User Operation

Test top-off injection
reduce residual beam oscillation due to injection kickers
emittance tuning with insertion devices
beam orbit stabilization with insertion devices
test and calibrate photon beam position monitors

## 7. Availability of Commissioning Software Tools for Commissioning

A fully functional list of application programs and software tools for use in the Control Room is assumed to be available at the time of commissioning. The following list captures a minimum functionality to assure efficient commissioning

## 7.1 General Operation Software

- Overall Status page
- Status, Alarm and Warning monitor
- Permit system monitor and control
- Data logger and data display
- Electronic logbook

## 7.2 Operations Software

- Accelerator parameter store/restore with file-manager, editing capability and possibility to smoothly ramp from one stage to another
- Injection Control
- Power supply control
- RF Control
- Slow orbit Feedback control
- Fast orbit Feedback control
- Fast Transverse Damper Control
- Front-end monitoring and control
- Machine protection system display and control
- Magnet temperature interlock display and control
- Scraper and Moveable Mask operations

Note:
Fast orbit feedback control implies –
- Use of cell controller for communication
- Use of cell controller for feedback processor
- Use of only fast correctors
- Feedback rate up to 10 khz
- Orbit correction  bandwidth up to 500 Hz

Slow orbit feedback control implies –
- Not to use cell controller, but use 10 Hz port for communication to all BPMs and correctors
- Use main computer for feedback processor
- Use only slow correctors
- Feedback rate up to 10 Hz
- Orbit correction bandwidth up to 1 Hz

During early stage of commissioning, slow orbit feedback control is preferred for following reasons –
- More robust, though lower orbit correction bandwidth
- Use of stronger magnet, so will have sufficient corrector capacity in case of larger orbit deviations.

## 7.3 Major Subsystem Control

- Power supply page which lists for all ps:  setting or waveform, read back, difference between DCCTs, status, recent history,
- RF page with all relevant settings, read back, status, parameters
- Vacuum display and control
- Cryogenics system display and control
- Pulsed magnet systems Monitor and Control

## 7.4 Beam Diagnostics

- Beam Orbit page with closed orbit, turn by turn, single turn, status information, difference (reference orbit display)
- Beam Current History and lifetime display
- Bunch intensity display and history
- Beam emittance display
- Injection element display and control page
- Timing system display and control
- Synchronization system display and control
- Tune display and control
- Temperature monitoring display

## 7.5 Safety Systems

- Personal protection system status display
- Equipment Protection Status Display and Control
- LCM Status display and Control
- Top-off Status Monitor
- Radiation area monitor status and display
- Fire protection system display

## 7.6 Utility Control

- Tunnel air temperature and humidity monitor
- Mechanical utilities status and control
- Electrical utilities status and controls
- Equipment enclosure monitor
- Water cooling system display
- Controls network monitor
- Air flow and pressure systems monitoring

## 7.7 Accelerator physics applications Toolkit

- Static orbit corrections,
- First turn steering,
- Chromatic correction,
- Response matrix measurements,
- Phase advance measurements,
- Beam base alignment of quadrupoles
- BPM test programs,
- Beam optics measurement,
- Beam based alignment of sextupoles,
- Analysis on nonlinear dynamics,
- Dispersion measurement and correction,
- Closed Orbit bump page

## 7.8 Injector Commissioning

The following applications will be used during the booster commissioning:

| Application | Purpose | Developed by |
|---|---|---|
| Orbit measurement and correction | Correct orbit | vendor |
| Tune measurement and correction | Correct tunes | vendor |
| Beam intensity and loss measurement | Charge control | vendor |
| Chromaticity measurement | Chromaticity control | vendor |
| Twiss parameters measurement | Optics symmetrization | vendor |
| Energy measurement | Measure energy | vendor and NSLS-II |
| Quadrupole scan | Measure extracted beam emittance and Twiss functions | NSLS-II |
| Energy spread measurement | Measure extracted beam energy spread | NSLS-II |

## 7.9 Accelerator logbook

An operations log book will be maintained and kept. This logbook will be fully electronic. Any application will able to print information into the control log. The logbook can only be accessed (for writing) from the control-room (controls-LAN). A mirror of the log-book will be accessible from offices and by secure remote access.

The purpose of accelerator logbooks is to provide an immutable history of machine status, machine operational problems and solutions, user problems and solutions, records of upgrades, records of machine studies and results and a history of initial commissioning of the facility with results and achievements of milestones.

The logbook will be fully electronic for entries by operators and other qualified control room staff for accelerator changes and set-up with one exception. A hard copy of the log is printed at the time of shift change, signed and dated by the operator of that shift and kept in a secure place. This is for legal implications in case of accidents, injuries and all other occasions where legal requirements have to be met.

Log entries can only be made from the control room by qualified personnel; changes cannot be made in an entry after it has been entered except by direct permission from facility chairman. All changes are only permitted if the original entry is not erased but only stricken out.

A log entry is accompanied by a time stamp at time of entry; time of actual occurrence is entered by the operator. It is assumed that a separate history program of accelerator parameters and conditions is running in parallel with the log time and can be used to verify the time of any changes in accelerator status such as a beam dump, RF levels etc. with enough resolution to facilitate problem diagnosis. This includes a fast high time-resolution history on a circular buffer which can be dumped by the operator within a reasonable time after an event occurrence.

A search feature should be built into the log program, so that past events can be easily found. A mirror of the logbook can be accessed for viewing from secure remote links. The logbook should be backed up on un-erasable medium in addition to the signed print-out at shift change.
Normally there are three types of logbooks kept for accelerator operations; two of them are subsets of the main operations logbook. The main logbook is the operations log; separate logbooks are kept for studies and for machine commissioning. The latter two logs do not require such stringent measures for security as the operations log. They will be used for staff information only but will ultimately be of historical significance. A studies request capability should be built into the studies log for recording machine changes, unusual parameter requirements and a studies results entry after completion. All studies should be authorized at the accelerator division or operations division head level.

# 8. Commissioning Organization and Staffing

## 8.1 Commissioning Organization

Accelerator commissioning is the responsibility of the accelerator systems division (ASD) of NSLS-II. The ASD director is ultimately responsible for commissioning. At this point, it is assumed that the project organization will extend to the end of commissioning.

Accelerator Commissioning is part of the NSLS-II project and is captured in the Pre-Operation part of the work break down structure under WBS's 1.6.02.05.1, 2, 3. In the commissioning period, the accelerator systems management will devote a large fraction of its effort to organize and supervise commissioning.

The organization of commissioning will be different for each part of the accelerator complex:

### 8.1.1 LINAC Commissioning

LINAC commissioning will be part of the LINAC turn-key contract with the LINAC vendor and will thus be the responsibility of the vendor. A NSLS-II lead and liaison will be defined which is the primary contact for the commissioning vendor. The NSLS-II lead will report as LINAC Commissioning taskforce leader to the ASD division director. Members of the injector group may support the taskforce leader. This group will form the LINAC commissioning team.

### 8.1.2 Booster Commissioning

Booster commissioning will be part of the Booster semi-turn-key contract with the Booster vendor and will thus be the responsibility of the vendor. A NSLS-II lead and liaison will be defined which is the primary contact for the commissioning vendor. The NSLS-II lead will report as Booster Commissioning taskforce leader to the ASD division director. Members of the injector group may support the taskforce leader. This group will form the Booster commissioning team.

### 8.1.3 Transfer line Commissioning

The beam-line and storage ring commissioning work will be organized in taskforces with a taskforce leader which reports directly to the division director. Members of the injector group and the accelerator physics group will support the taskforce leader as run coordinators. Transport line commissioning will be handled in the same way as storage ring commissioning (see below). This group will form the Booster commissioning team.

### 8.1.4 Storage Ring Commissioning

There will be a Storage Ring Commissioning Phase I and a Storage Ring Commissioning Phase II. They will be handled the same way. Phase II is expected to have a very strong participation of the insertion device group.

The beam-line and storage ring commissioning work will be organized in taskforces with a taskforce leader who reports directly to the division director. The taskforce leader will be assisted by run coordinators which serve for a limited period and which will have a high presence in the control room on top of the accelerator physicist and operator on duty. When on shift, the commissioning crew will report to the run coordinators who in turn will report to the commissioning taskforce leader. There is also a chief operator which will assist the run coordinators and task force leader in their safety function. He is the immediate the authority safe operations.

Note that operations will only be organized during commissioning that way. The taskforce leader, the run coordinators, the involved accelerator physicists, the chief operator, the operators, and the technical experts will form the commissioning team. This structure is orthogonal to the group structure in ASD and will not change the supervisory responsibility of the group leaders. Group members may be considered as delegated or assigned to the commissioning team and will report in this function to the run coordinators and the commissioning task force leader.

ASD management's strong involvement in commissioning as well as in the technical tasks of completing the project will make sure that conflicting interests of groups and commissioning teams are properly mitigated.

The physicist on duty will be responsible for carrying out commissioning tasks. He assist the will assist the crew chief and the run coordinator in making sure that safety regulations and rules are followed as specified in operational procedures and that ALARA principles are obeyed carefully.

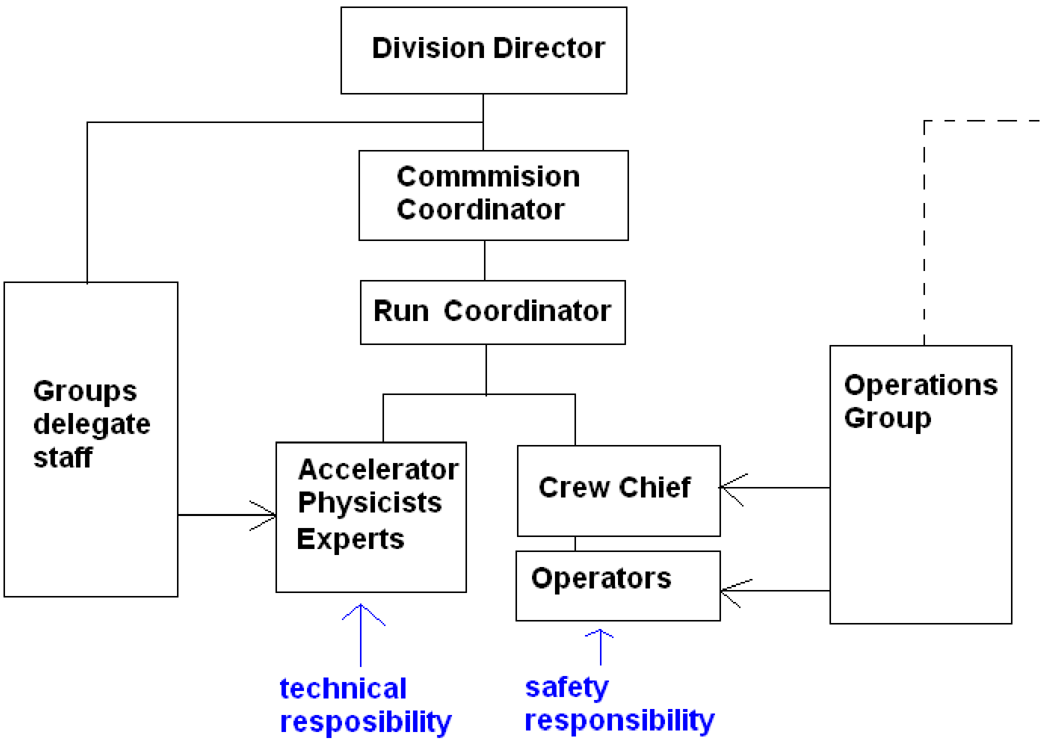



Figure 7.1: Commissioning Organization Chart

The commissioning taskforce is charged with the following:

- Organize the commissioning task shift operation in the control room
- Perform commissioning tasks
- Initiate analysis of commissioning results and the feedback of this process into the commissioning process
- Communicate the commissioning results
- Refine and develop the commissioning program
- Schedule intervention and request engineering support if the commissioning program or an unscheduled occurrence requires it.
- Assure that all tasks will be well prepared and tasks are carried out according to safety regulations

### 8.1.5 Commissioning Times

Commissioning will be organized in 3 shifts per day and seven days per week.

It is assumed that two subsequent shifts will have an overlap of at least ½ hour to assure continuity of the commissioning tasks and proper information of the incoming shift.

### 8.1.6 Emergency Response during Commissioning

Handling of failures and emergencies will follow strict escalation rules to make sure that the impact of non-planned occurrences is minimized. Such escalation plan will be part of the operational procedures which will be generated in the process of receiving the approval for commissioning.

## 9. Commissioning Staffing

### 9.1 General

Commissioning of the NSLS-II accelerator complex is part of the NSLS-II project and labor to perform the commissioning has been budgeted for. To perform commissioning, part of the accelerator systems which are already commissioned need to be operated. The labor to operate completed parts of accelerator systems needed for commissioning has not been budgeted for within the NSLS-II project.

Commissioning will require the presence of ESH staff members and matrixed individuals, especially staff from the Radiological Control Division. Radiological Control technicians must be available for each shift that the accelerator is operating.

The commissioning will require the involvement of accelerator physicists, the experts on the technical components and operators. The physicist's and engineer's involvements have been budgeted for. The operators will need to be covered by operational funds.

Commissioning will be carried out 24 h a day and 7 days a week. It is assumed that the workload of off-hour shifts will be shared between all members of the accelerator physics group and the technical experts on the subsystem.

Radiation protection staffing is planned to accompany the commission, especially during periods when high losses are expected (first injection, high intensity commissioning, dedicated test of shielding walls). The planned resources will not be adequate to handle 24 periods, seven day for the entire commissioning period of for 33 weeks.

It is assumed the engineers and technicians will be on call during commissioning to be able to resolve any technical issue during commissioning immediately.

It is assumed that the control room will be manned with at least one accelerator physicist during the entire commissioning of ~33 weeks. This requires about 16000 working hours which has been budgeted for. The involvement of engineers will be less regular and will depend on the commissioning program to be pursued.

## 9.2 Assumption on Involvement of Operators in Commissioning

For start up of commissioning, it is assumed that 1 machine operator will be present on every shift. This will gradually develop into a mode with 2 operators and no accelerator physicists.

NSLS-II will not start its own operations group but will use members of the existing control room group of NSLS. Supervisory relationships will not have to be changed. Details of the involvement of the NSLS operations crew in NSLS-II commissioning will depend on details of the NSLS-NSLS-II integration process which is under development at this time (Jan 2010).

## 9.3 Assumptions on Involvement of NSLS Staff in Commissioning

NSLS has 85 highly trained staff which is responsible for operating NSLS. At this point no definite plans for the decommissioning of NSLS have been made and the availability of the staff for NSLS-II commissioning activities is unknown. It is assumed that part of the NSLS staff will participate in commissioning and that NSLS operators will be trained to operate NSLS-II whenever the staff will become available. There are no plans within the project for an NSLS-II operating organization at this point. Such plans need further development of plans for NSLS and NSLS-II integration. At this point it can be assumed there will be a procedure in place for NSLS staff involvement, be it via NSLS-NSLS-II integration or NSLS-II-NSLS MOU. The development of this part of the start-up and commissioning plan will be fully aligned with the NSLS-NSLS-II integration process.

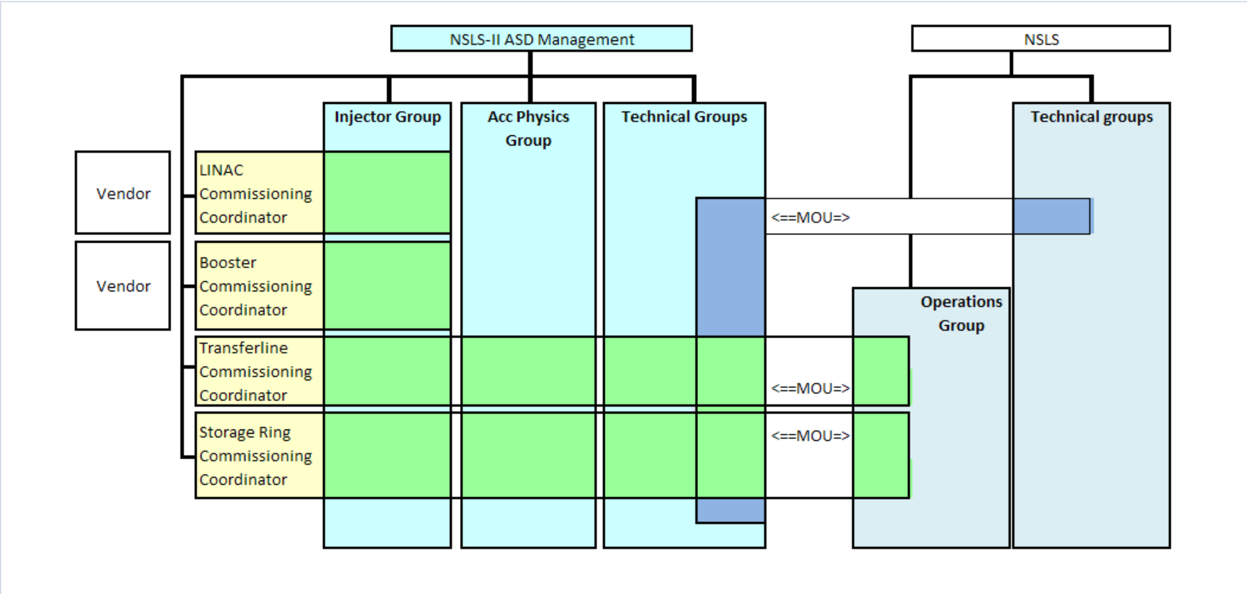



Figure 8.1 NSLS-II Commissioning Organization Chart

## 10. Interference with Beam Line Construction

Commissioning activities should be communicated with staff building and installing experimental beam lines. XFD will define points of contact which will communicate relevant information and handle any emergency measures on the experimental floor.

## 11. Commissioning Information and Documentation

It is assumed that there will be semi-formal commissioning meetings of 15 min at the beginning of each shift which should be attended by the out-going and in-coming shift crews. The meeting will allow a seamless transition from one shift to the next and provide an opportunity to communicate and discuss fine-tuning of the commissioning program. It is assumed that there will be 3 shifts per day and thus there will be three such meetings.

A weekly commissioning meeting will summarize the commissioning results. Based on the discussion of the results, it will provide opportunity to optimize the commissioning program and direction. The weekly commissioning meetings will be documented including all material presented.

The commissioning will be carried out in commissioning modules. Each module requires a written plan which indicates the purpose, the goal, supporting documents, results of calculations necessary to carry out the module, an estimate on the needed machine time and the labor resources required. The results of each module will be documented. The raw data will be stored in an organized and accessible way. The evaluation of the data, resulting set-points and procedures and parameters will be documented in an evaluation document.

At the end of commissioning, a report will be published which is based on the commissioning module evaluation documents.

## 12. Accelerator Control Room during Commissioning

The accelerator control room is the location where the operations staff control and monitor the machine status and functions, such as injection, automatic top-off, orbit changes and adjustments, etc, in other words all functions dealing with the health of the accelerator complex. In the control room, the following functions are carried out or available:

- Operators operate the accelerator,
- Operators coordinate with technical staff about technical difficulties and interventions, call in appropriate personnel for repairs during off-hours
- Accelerator experiments and approved studies are carried out
- The logbook on accelerator operations is kept and maintained
- Information in case of an emergency is to be obtained and delivered to emergency personnel called to the facility
- Day-to-day coordination between accelerator and experimental floor are exchanged
- Shift-change briefing meetings are held

- First hand information on the status of the accelerator is available
- The responsibility for operating the accelerator safely within the Accelerator Safety Envelope and other safety requirements resides
- Routine safety measures such as LOTO and coordination with ES&H occur regarding limitation of access to building areas where elevated radiation levels may be present due to unusual machine operations
- Preparation of the accelerator for operations is coordinated after an interruption,
- Special monitor screens are installed to provide an optimized selection of displays for quick overview of accelerator status
- Emergency stop buttons are installed
- Special installations have been made (controlled LAN connections, access to facility wide audio system etc.)
- Where all building access points are monitored 24 hr a day 7 days a week
- The only place in the facility which is manned at all times except during special conditions such as for an extended shutdown.
- Provides central location for coordination with BNL emergency response staff
- Control room will include a fire pre-alarm response system and a fire alarm pull station to evacuate the building

The control room also functions as emergency coordination center and focal point for emergency status for building occupants. The control room monitors fire detection panels, has capability to communicate with lab emergency personnel by radio to direct them to the appropriate building entry point. Lab-wide emergency broadcasts on the Tone Alert Radio system are also monitored and emergency information communicated building-wide.

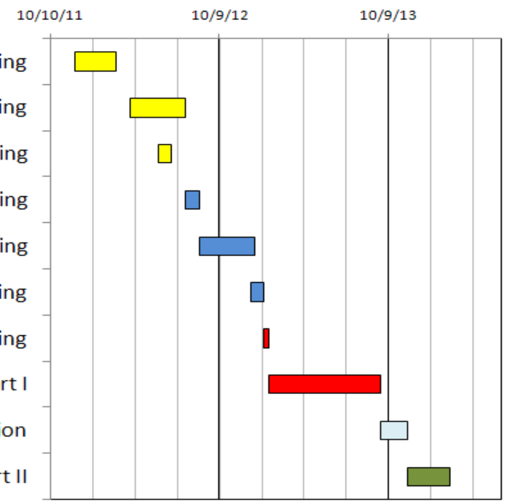
This functionality of the control room is not very different between commissioning and operation but at commissioning it is highly desirable that the control room is close to the accelerator hardware. It is assumed that there will be a temporary control room in the injector and the ring-building during commissioning. It may also be necessary to have two machine operators available during the commissioning period, cross-training among operators and operations coordinators may be helpful during this time.

It is assumed that the control room LAN is accessible from the accelerator tunnel and from the mezzanine. Wireless LAN access is under consideration.
It is assumed that the minimum requirement for a provisory control room for commissioning is controls LAN access. No special computer hardware is required.

## 13. Commissioning Schedule

The commissioning schedule is laypout out in the table below. Actual start and end date may change slightly which will become clear once the projects progresses.

| Start | End | Dur | |
|---|---|---|---|
| 12/1/2011 | 2/29/2012 | 90 | LINAC Front end Commissioning |
| 3/30/2012 | 7/28/2012 | 120 | LINAC Commissioning |
| 5/29/2012 | 6/28/2012 | 30 | LBTL in LINAc Commissioning |
| 7/28/2012 | 8/27/2012 | 30 | LBTL Commissioning |
| 8/27/2012 | 12/25/2012 | 120 | Booster Commissioning |
| 12/15/2012 | 1/14/2013 | 30 | BSTL in Booster Tunnel Commissioning |
| 1/14/2013 | 1/24/2013 | 10 | BSTL Commissioning |
| 1/24/2013 | 9/21/2013 | 240 | Storage Ring Commissioning Part I |
| 9/21/2013 | 11/20/2013 | 60 | ID Installation |
| 11/20/2013 | 2/18/2014 | 90 | Storage Ring Commissioning Part II |




## 14. Commissioning Budget

Table 12.1 provides an overview of the budget for accelerator pre-operations and commissioning.

| WBS | | resource | | FY11 | FY12 | FY13 | FY14 | | Cumulative |
|---|---|---|---|---|---|---|---|---|---|
| 1.06 | Pre-Operations | | 0 | 701,539 | 4,486,150 | 11,124,437 | 9,893,919 | 0 | 26,206,045 |
| 1.06.02 | Accelerator Systems - Pre Ops | | 0 | 701,539 | 4,486,150 | 7,500,344 | 4,383,558 | 0 | 17,071,591 |
| 1.06.02.01 | Accelerator Management Support - Pre Ops | | 0 | 404,814 | 496,992 | 512,316 | 466,589 | 0 | 1,880,711 |
| 1.06.02.02 | Accelerator Machine Physics - Pre Ops | | 0 | 265,886 | 368,281 | 307,699 | 0 | 0 | 941,866 |
| 1.06.02.03 | Operations Development | | | 30,840 | 63,652 | 624,225 | 284,894 | 0 | 1,003,610 |
| 1.06.02.04 | Integrated Testing | | | 0 | 2,202,629 | 3,703,594 | 0 | 0 | 5,906,223 |
| 1.06.02.05 | Accelerator Commissioning | | | 0 | 1,354,596 | 2,352,509 | 3,632,075 | 0 | 7,339,180 |
| 1.06.02.05.01 | Accelerator Commissioning Management | | 0 | 0 | 1,354,596 | 1,428,121 | 1,018,274 | 0 | 3,800,990 |
| 1.06.02.05.02 | Accelerator Injector System Commissioning | | 0 | 0 | 0 | 924,389 | 0 | 0 | 924,389 |
| 1.06.02.05.03 | Accelerator Storage Ring Commissioning | | 0 | 0 | 0 | 0 | 2,613,801 | 0 | 2,613,801 |
| | | LE1 Electrical Engineer | | 0 | 0 | 0 | 234,765 | 0 | 234,765 |
| | | LE2 Mechanical Engineer | | 0 | 0 | 0 | 50,566 | 0 | 50,566 |
| | | LE6 Computer Analyst (IT) | | 0 | 0 | 0 | 653,396 | 0 | 653,396 |
| | | LE7 RF Engineer | | 0 | 0 | 0 | 205,470 | 0 | 205,470 |
| | | LO2 Electrical Designer | | 0 | 0 | 0 | 143,553 | 0 | 143,553 |
| | | LO3 Mechanical Technician | | 0 | 0 | 0 | 38,821 | 0 | 38,821 |
| | | LO4 Electrical Technician | | 0 | 0 | 0 | 67,780 | 0 | 67,780 |
| | | LO5 Electronics Technician | | 0 | 0 | 0 | 147,884 | 0 | 147,884 |
| | | LO6 RF Technician | | 0 | 0 | 0 | 152,507 | 0 | 152,507 |
| | | LO7 Vacuum Technician | | 0 | 0 | 0 | 23,107 | 0 | 23,107 |
| | | LS1 Scientist | | 0 | 0 | 0 | 771,608 | 0 | 771,608 |
| | | LS2 Assistant/Associate Scientist | | 0 | 0 | 0 | 41,320 | 0 | 41,320 |
| | | LX5 Plant Engineering Building Trade | | 0 | 0 | 0 | 83,025 | 0 | 83,025 |

## 15. Funding for Commissioning

An assumption is made that additional early operation funding will be available to support operation of already commissioned systems (injector, cryo-plant) and other subsystems.
It is also assumed that early operational funds will be available to cover for the expected high level of technical trouble shooting necessary for operation and commissioning.

The expected level of early operational funding which is not covered by the project budget required is ~70FTE.